October 2006

Technical Series 06-108

Field Assessment of a NuAir AIMS (ēKOCOMFORT™) Unit

INTRODUCTION

CMHC (Canada Mortgage and Housing Corporation), in partnership with Enbridge Gas Distribution, evaluated the reliability of two integrated space and water heating systems to determine the combo systems' energy use and operating costs, and compare these systems with a hypothetical reference system.

The hypothetical reference system, representative of the systems that had been installed and used at these sites before the project, were an electric, forced-air furnace and an electric, storage-tank water heater. The homes are in the Enbridge Greater Toronto market area.

Gas-fired combo space and water heating systems were retrofitted into two similar town homes that had previously used electric furnaces for space heating and electric, storage-tank water heaters for water heating. Both installations used a new Enerboss™ integrated HRV/air handler that provides an integrated ventilation and heat recovery function as well as space heating. For water heating, one of the homes (Unit 25) used a Rinnai™ tankless water heater, while the other (Unit 30) used a GSW™ combo storage-tank water heater.

The format for the test and monitoring were based on a protocol that was being used to evaluate early Advanced Integrated Mechanical Systems (AIMS)[1] prototypes in a parallel project.

RESEARCH PROGRAM

The two combo systems were installed, inspected and commissioned between September and November 2003. The Rinnai installation in Unit 25 was later than the tank-based system in Unit 30, because it replaced a different integrated boiler system that had briefly been tested in Unit 25.

The systems were deemed fully operational and were monitored from December 22, 2003 until September 24, 2004. Although the pulse outputs from the battery-powered energy meters in Unit 30 were not being accumulated by the data loggers until later, the energy meters were correctly measuring and storing data in their internal registers from the time that they were installed. As a result, space and water heating data were available for Unit 30 for a full year. For Unit 25, full data was available from December 2003 until monitoring ended, with some additional space heating data available prior to December 2003. However, control settings and piping modifications for the Rinnai component in Unit 25 were not finalized until the end of November 2003.

[1] AIMS is an acronym that was used for an industry-federal government initiative that provided guidance and support to a number of manufacturing groups that enabled them to develop more advanced integrated HVAC systems for Canadian homes and apartments. The ēKOCOMFORT™ trademark was developed by the AIMS group for future use with such products and the AIMS group became known as the ēKOCOMFORT consortium.

THE HOMES

The units varied slightly, but generally consist of:

- An upper floor with three bedrooms and a washroom
- A main floor with a kitchen, hallway, and dining room
- A basement area with storage, a second finished room and a washroom. In both monitored sites the mechanical room or furnace room is on this floor
- In both houses there is a garbage room "attached but in front of the front door"
- Each unit has a patio accessed from the kitchen by a double, sliding patio door .
- Each unit has a second-floor balcony.

The total living space in each unit is about 111.4 m² (1,200 sq. ft.) with each unit having a design heat loss of 12 kW at a design temperature of -20°C (68°F). Both units are rented; Unit 25 had one tenant and Unit 30 initially had two tenants; increasing to three during the test period.

THE COMBINED SPACE AND WATER HEATING (COMBO) SYSTEMS

Each combo system consisted of an Enerboss™ integrated HRV/Airhandler and a different boiler package for each site. The NuAir Enerboss air handler uses a water-to-air coil for space-heating energy. The two installations are characterized as follows:

UNIT 25

An Enerboss™ 500 series air handler was installed, complete with 1.8 t (2 tn) of cooling and an integrated HRV. The boiler package consists of one Rinnai™ model V2532 continuum water heater. An anti-scald blending valve was installed on the domestic potable water side of the system. The air handler was installed in the basement mechanical room and the Rinnai system in the outside enclosed garbage room. In order to protect the water heater from the environment, two Asco™ solenoid valves were installed, one normally open and one normally closed. This protection allowed the unit to dump its internal water in the event of freezing or power failure.

Product specifications

Air handler:	Enerboss™ Integrated Air handler/HRV
Heat generator:	Rinnai™ Model V2532 FFU instantaneous water heater; 15,000 to 180,000 Btu/h input; installed in an ante-room/garbage/storage room adjacent to the townhouse unit.

Based on manufacturer's specifications, the Rinnai water heater has a rated EF of 0.82.

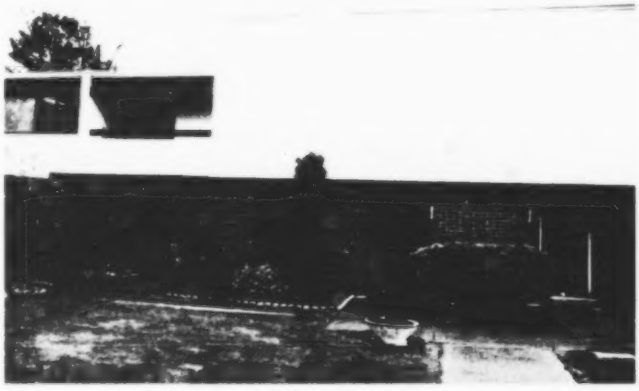

Photo 1–Front view of Unit 25

UNIT 30

An Enerboss™ 500 series air handler, identical to the one in Unit 25, was installed as described above. The boiler package consists of a GSW Superflue™ 6 power vented water tank. According to the manufacturer, this component was specifically designed for combo systems. As in Unit 25, an anti-scalding valve was installed. As the air handler and the water tank were installed in the basement mechanical room, there was no need to install a dump system.

Product specifications

Air handler:	Enerboss™ Integrated Air handler/HRV
Heat generator:	GSW Superflue™ 6 power vented storage-tank water heater; model number 6G5065SNV04; Serial number S0303500975; 189 L (41.5 gal.) tank; 58,500 Btu/h input

The water heater tank has a rated EF of 0.58, based on specifications obtained from GSW.

THE MONITORING PACKAGES

The instrumentation package and data acquisition program for this project were developed by the AIMS/eKOCOMFORT™ consortium. The instrumentation package for each monitored site consisted of:

- Two Kamstrup™ energy meters, each comprising a water-flow meter, two temperature probes and a battery-powered electronics module
- 11 thermocouples
- An in-line electricity meter with pulse output
- A fuel-valve timer and isolating relay to monitor burner on-off operation
- Status relays to signal control-operating modes to the data logger
- One Campbell Scientific™ CR10X data logger

The Kamstrup energy meters were installed to measure water flow through the space-heating coil of the NuAir Enerboss air handler, with the temperature probes of the energy meters installed to monitor the inlet and outlet water temperature across the heating coil.

For the water heating sections of the integrated systems, the energy meters were installed to measure the cold water flow into the units with the temperature probes installed to measure the water temperatures into and out of the units (after the anti-scald blending valves). At each site, one energy meter was used to measure the space-heating energy output while one was used to measure the energy output associated with domestic hot water.

The battery-powered Kamstrup energy meters continuously monitor water flows and the temperature difference between their water-temperature probes. The meters calculate energy flow from those measurements and hold the measurements in internal data registers.

Researchers visited the site every 40 days to avoid losing data from the energy meters.

During each site visit, the homeowners (if present) were asked whether there were any concerns about the systems. The systems were visually checked for signs of pending problems, leakage and so on. Manual readings were taken from the utility billing meters and the sub-metered electricity meter for the integrated system. During certain site visits, spot measurements of system temperatures and flows were taken and combustion efficiency tests were performed on the systems using a portable combustion analyzer.

The data analysis procedure was primarily based on using the Kamstrup energy meters to determine the heating and hot water outputs from the integrated systems during a given time period. Readings from the utility billing meters and sub-metered electricity readings were used to determine the energy inputs into the integrated units for the same time period. This approach allowed the overall system performance to be calculated for each time period, and over the course of the project allowed the system part load performance to be determined from the measurements.

RESEARCH FINDINGS

Combustion efficiency

Combustion efficiency is an indicator of the performance of the system while the burner is operating. It does not account for any system losses during standby or any losses in the distribution systems (for example, heat lost from a hot water storage tank, pipes or ductwork). Site measurements to determine combustion efficiency were taken with a portable combustion analyzer and are summarized in Tables 1 and 2.

Table 1–Unit 25: Rinnai system combustion efficiency measurements

Date	Flue temp (°F)	O_2 (%)	CO (PPM)	Efficiency (%)	Comments
12/22/03	163	15.5	22	83.4	DHW Load
4/16/04	150	17.5	13	82.9	Heating
7/16/04	151	15.7	19	85.9	DHW Load

Table 2–Unit 30: Combo tank system combustion efficiency measurements

Date	Flue temp (°F)	O_2 (%)	CO (PPM)	Efficiency (%)	Comments
4/16/04	158	18.4	0	78.9	Recovery, near end
7/16/04	154	18.4	0	80.0	Recovery

The combo tank water heater has a fixed burner input, with the burner operating at the same input to heat the water in the tank to the set point temperature when needed (see table 2).

By contrast, the Rinnai tankless water heater has a modulating burner that can adjust its firing rate to match the load, allowing it to reduce its capacity for small loads, which may account for the higher efficiency measured for the Rinnai during summer water heating. The efficiency of tank-based water heaters varies slightly as the water temperature in the tank increases, with the efficiency at its lowest value just before burner shutoff, when the water temperature in the tank reaches its maximum level (see table 1).

Based on the measurements, the combustion efficiency of the Rinnai tankless water heater was slightly higher than the combo tank.

OVERALL THERMAL EFFICIENCY

Overall thermal efficiency was calculated for various time intervals during the project by summing the space and water heating energy outputs from each system and dividing the total by the energy input. The performance of the two systems was similar during periods with high loads, with the overall performance of both systems falling with reduced system loading. However, the efficiency of the tank-based system fell faster than the efficiency of the tankless system as the load was reduced. This may be attributed to the constant standby losses from the storage tank, which has a greater impact on system efficiency when the loads are low.

Part load comparison with other HVAC equipment

Reduced system performance at low system loads was also observed with other types of HVAC equipment. Figure 1 shows the part-load performance curve used in the DOE-2 computer program to model the performance of HVAC equipment.

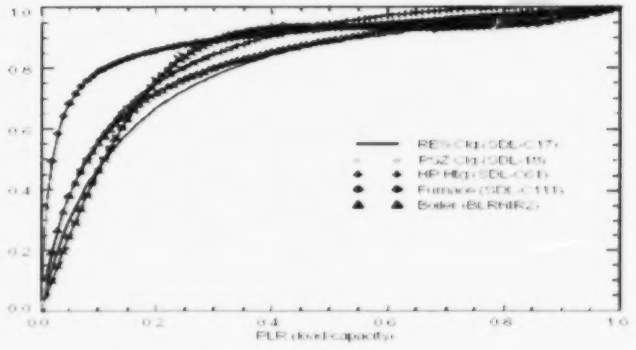

Figure 1–PLF vs PLR

Part load ratio (PLR) is the system output divided by the system's design output.

Part load factor (PLF) is the system's (efficiency) divided by the system's efficiency at its full load design condition.

Operating cost comparisons with electrical alternative

The following assumptions were made to compare the cost of operating the two combo systems with the hypothetical baseline electric system:

- The electric alternative system was assumed to use electric resistance elements having a space heating efficiency of 100 per cent and a water heating Energy Factor (EF) of 0.92, equivalent to a water heating efficiency of 92 per cent.
- Costs for electricity and natural gas were taken from the prevailing rates at the site during the monitoring period, including GST. The rates were:
- $0.0976 / kWh for electricity
  $0.476 / m³ for natural gas

The measured space heating loads for Unit 25 were typically higher than for Unit 30, while the water heating loads were lower. Overall, the combined loads for the two sites were similar. To enable analysis of the operating costs for a full year at both sites, load data from Unit 30 were used for Unit 25 for the period between September and December 2003.

CONCLUSIONS

The two combo systems provided all of the space heating and water heating loads that were required at the sites. In addition, the advanced combo air handlers provided the occupants with controlled ventilation and heat recovery when they chose to operate their ventilation systems.

In general, the tenants stated that they were happy with the performance of their combo systems, although there were initially some complaints about delays in obtaining hot water from the system in Unit 25. Shortly after the monitoring portion of this project was completed, new tenants moved into that unit. Based on anecdotal information, the new tenants have been happy with the performance of their system.

The part-load performance results indicate that the efficiency of the tankless system was slightly higher than the tank-based system when the loads were high (that is, during the heating season). The tankless system was considerably more efficient than the tank-based system during periods with low loads.

Based on analysis of the monitored data, and the prevailing gas and electricity rates during the monitoring project, over one year the tankless combo system in Unit 25 consumed 3,041 m^3 natural gas (107,352 cu. ft.), at a cost of $1,446. To provide the same loads, the electric alternative would have used 23,807 kWh of electrical energy at a cost of $2,324. The gas-fired combo system in Unit 25 saved $878 per year, or 38 per cent, compared with the electric alternative.

The tank-based combo system in Unit 30 consumed 3,381 m^3 natural gas (119,349 cu. ft.) over the year at a cost of $1,608. To provide the same loads, the electric alternative would have used 25,368 kWh of electrical energy at a cost of $2,476. The gas-fired combo system in Unit 30 saved $868 per year or 35 per cent compared with the electric alternative.

REFERENCES

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LBNL-42175, Residential Equipment Part Load Curves for Use in DOE-2, Lawrence Berkeley National Laboratory et al. February 1999 for the U.S. Department of Energy

CMHC Project Manager: Bill Semple, Senior Researcher

Consultant: Peter Edwards Company

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or contact:

Canada Mortgage and Housing Corporation
700 Montreal Road
Ottawa, Ontario
K1A 0P7

Phone: 1-800-668-2642
Fax: 1-800-245-9274

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Printed in Canada
Produced by CMHC 13-10-06

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